

RESTRICTED

B-24D

Report No. ZI-32-068

OPERATING INSTRUCTIONS

FOR

BALODIAL

MODEL B-24D FOUR ENGINE BOMBERS

CONTRACT No.

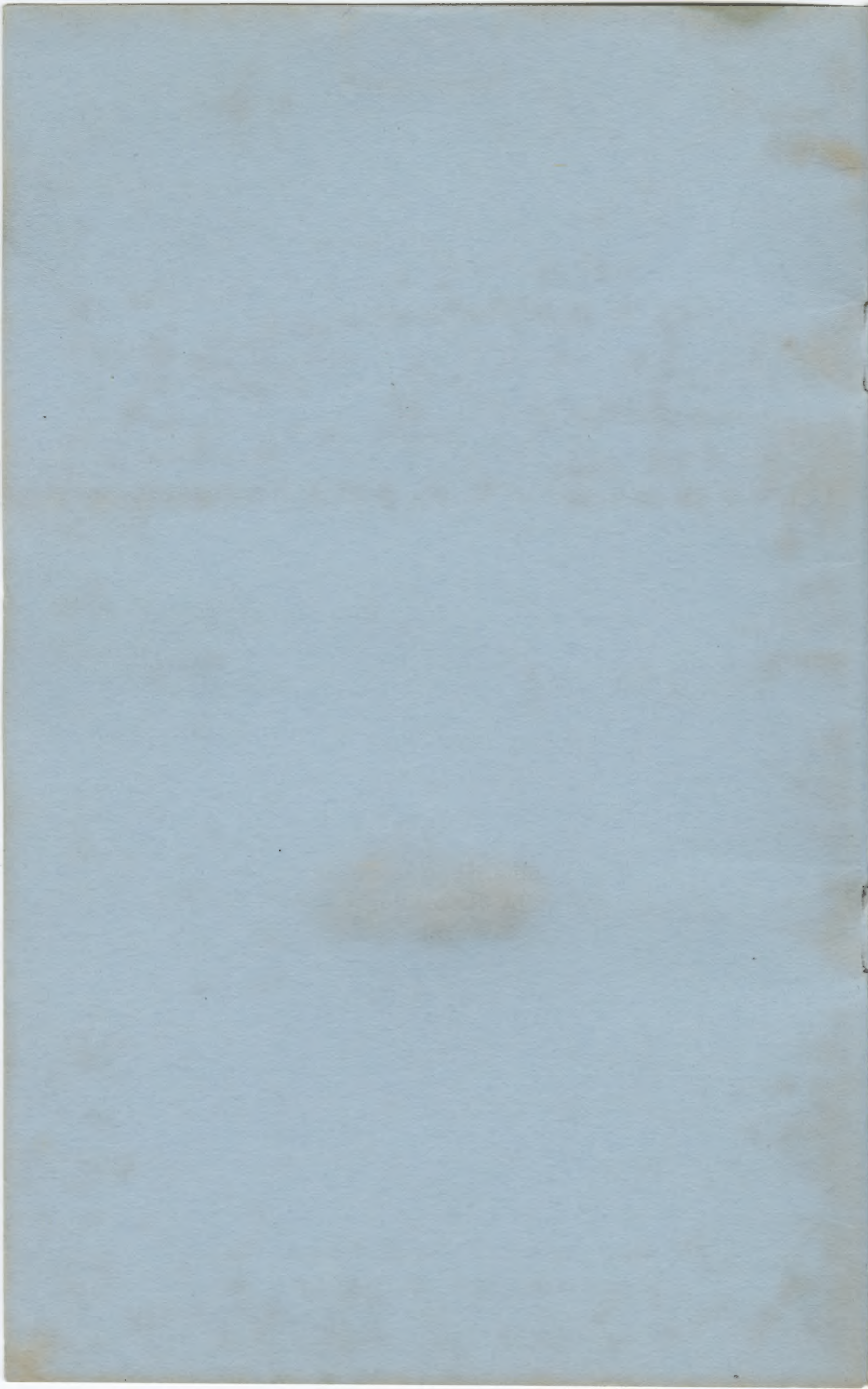
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CONSOLIDATED AIRCRAFT CORPORATION
SAN DIEGO, CALIFORNIA

RESTRICTED



RESTRICTED**MODEL B-24D****INDEX**

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CONSOLIDATED AIRCRAFT CORPORATION
SAN DIEGO, CALIFORNIA

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FOREWORD

The determination of gross weight and fore and aft center of gravity (C.G.) location for a particular airplane loading condition has always been important in order to make certain that the gross weight is not excessive and that the C.G. location is such that the controllability and stability of the airplane is satisfactory.

It is doubly important today that the gross weight and C.G. location be determined for each loading, since wartime conditions often call for carrying the maximum possible load even though the utilization of available space may sometimes result in an excessive gross weight and/or an unsatisfactory C.G. location.

The mathematical computation of gross weight and C.G. location is often a rather laborious operation, sometimes requiring as much as one-half hour to a full hour's time of one who is familiar with the principles of C.G. calculation.

In order to reduce the time of gross weight and C.G. determination to a negligible item, and to make possible the computation by flight personnel who may not be familiar with routine C.G. calculations, the Balodial was developed. As its name implies, the Balodial (which consists of several dials) computes balance and load.

DESCRIPTION

General

The Balodial consists mechanically of four elements: a large dial, two concentric smaller dials mounted on either face of the large dial, and a transparent radial index arm assembly with radial hair lines on either side. All elements have a common center and are capable of being rotated relative to one another.

Balodial Elements for Gross Weight Determination

On one face of the large dial is a **weight scale** graduated in pounds.

Mounted on this face is a rotating dial which is divided into six (6) sectors (numbered from 1 through 6), each representing a category of variable load: Crew, Fuel, Oil, Ammunition, Bombs and Cargo. In each sector is a zero line (radial dotted line). From this zero line originate one or more **variable load scales** graduated in various units, e.g., number of crew members, gallons of fuel, etc.

Use of the **index arm** in conjunction with the **weight scale** of the large dial and the rotating dial **variable load scales**,

makes possible the determination of the gross weight of the airplane for a particular loading provided the initial weight (Balodial Basic Weight) is known.

Balodial Elements for Center of Gravity Determination

On the other face of the large dial is a **"C.G.-Weight grid"** consisting of a series of equally spaced concentric lines (representing progressive values of gross weight) crossed by lines marked in terms of center of gravity (C.G.) in feet aft of the Datum Line.

Mounted on this face is a rotating dial which is divided into two main sectors; one representing **"Variable Load Items,"** the other marked **"C.G. Adjustment."**

The first main sector marked **"Variable Load Items"** is divided in turn into six (6) sectors (numbered from 1 through 6) representing the same categories of variable load as represented by the six sectors on the rotating dial used in determining gross weight. In each sector is a zero line (radial dotted line) from which originate **variable load scales** graduated in various units, e.g., number of crew members, gallons of fuel, etc.

The second main sector marked **"C.G. Adjustment"** contains:

(a) A **"cargo weight-station location grid"** consisting of a series of circular arcs (representing progressive values of weight of equipment or cargo to be moved) crossed by a series of lines numbered consecutively and representing Station numbers or locations in the airplane. (See Station Diagram, Page 16.)

Use of the **index arm** in conjunction with the **"C.G.-Weight grid"** of the large dial and the **variable load scales** of the rotating dial makes possible the determination of the C.G. of the airplane for different loading conditions.

Use of the **index arm** in conjunction with the **"C.G.-Weight grid"** of the large dial and the **"cargo weight-station location grid"** of the rotating dial's **"C.G. Adjustment Sector"** makes possible the relocation of cargo or equipment to obtain a desired C.G.

(b) A **"Crew Location" scale.**

Use of the **index arm** in conjunction with the **"C.G.-Weight Grid"** of the large dial and the **"Crew Location" scale** of the rotating dial's **"C.G. Adjustment Sector"** makes possible the relocation of one (1) crew member to obtain a desired C.G. or the determination of the change in C.G. due to moving (1) crew member from one location to another.

OPERATING INSTRUCTIONS

General

In operating the Balodial, maximum speed and ease of operation can be obtained if the Balodial is handled as follows:

Hold the Balodial approximately horizontal in the left hand so that it is supported by the four fingers held on the under side and by the pressure of the edge of the large dial against the palm of the hand. The thumb of the left hand can then be used to rotate the smaller dial.

The thumb, index, and middle finger of the right hand are used to move and to hold the index arm stationary relative to the large dial.

(A) Gross Weight Determination (Use Side with Weight Scale)

Set index on Balodial Basic Weight (See pages 9 to 14).

Add in following manner the variable load items to be carried:

Move rotating dial until zero line (dotted radial line) for particular item to be added coincides with index line.

With dials fixed relative to each other, move index arm until it intercepts scale of item at proper number or quantity.

Repeat this operation for each variable load item to be carried and read the **Gross Weight** on Weight Scale.

(B) C.G. Determination (Use Side with Center of Gravity-Weight Grid)

Set index on "C.G. Grid" at point corresponding to Balodial Basic Weight and C.G. (See pages 9 to 14).

Add in following manner the variable load items to be carried:

Move rotating dial until zero line (dotted radial line) for particular item to be added coincides with index line.

With dials fixed relative to each other, move index arm until it intercepts scale of item at proper number or quantity.

Repeat this operation for each variable load item to be carried, and read the **Gross Weight C.G.** on the "C.G. Grid" at the gross weight value obtained in "A."

(C) C.G. Adjustment by Relocating Crew or Cargo

If a different gross weight C.G. value from that obtained in "B" is desired, it may be possible to obtain the desired C.G. by either relocating crew members or shifting cargo.

(1) By Relocating One Crew Member

Set the index on the "C.G.-Weight Grid" at a point corresponding to the gross weight and C.G. obtained in "B."

Move the rotating dial until the "Crew Location" Scale in the "C.G. Adjustment Sector" crosses the index hair line at the scale division corresponding to the location of the crew member to be moved.

With the dials fixed relative to each other, move the index arm to the desired value of C.G. (at same gross weight).

On the "Crew Location" scale where the index hair line then crosses, read the location to which the crew member must be moved.

(2) By Relocating Cargo

Set the index on the "C.G.-Weight Grid" at a point corresponding to the gross weight and C.G. obtained in "B."

Move the rotating dial until the point of intersection of the cargo weight and cargo location lines (on "Cargo Weight-Station Location grid" of "C.G. Adjustment Sector") falls on the index line.

With the dials fixed relative to each other, move index arm to desired value of C.G. (at same gross weight).

On the "C.G. Adjustment Sector," where the index line then crosses the circular arc representing the weight of cargo to be moved, read the Station location to which the cargo must be moved.

Note: The weight of (1) crew member (200 lbs.) or the weight of cargo moved may not be sufficient to give a desired C.G.

The effect on the C.G. of moving a crew member or a certain weight of cargo from one location to another, can however be determined. See Example 3.

EXAMPLES

1. Gross Weight and C.G. Determination

Required: To find the Gross Weight and Center of Gravity of B-24D airplane, Serial No. 41-11741, when loaded as follows:

Crew (4)

Pilot	(1)
Bomber (at nose compartment)	(1)
Top Gunner	(1)
Tail Gunner	(1)

Fuel & Auxiliary Tanks

Fuel—Main Wing Tanks ...	1800 U. S. Gals.
Front Bomb Bay Tanks.....	(2)
Fuel—	
Front Bomb Bay Tanks..	600 U. S. Gals.
Oil	120 U. S. Gals.
Bombs—2000 lbs. Class.—AFT. BAY.....	(2)
Cargo—Vicinity of Station No. 7.2.....	400 lbs.

(a) Gross Weight Determination

Using the side of the Balodial on which the weight scale appears:

First set the index hair line on the "Basic Balodial Weight" of 33,600 pounds (see "Basic Balodial Weight," page 10).

Move the rotating dial until the zero line (dotted radial line) of Sector "1" (Crew) coincides with the index hair line.

With the two dials fixed relative to each other, move the index until its hair line intersects "4" (the number of crew members to be carried) on the scale.

With the index arm held stationary relative to the large dial, move the rotating dial until the zero line of Sector "2" coincides with the index hair line.

With the two dials fixed relative to each other, move the index until its hair line intersects the scale marked "Fuel—Main Wing Tanks (U. S. Gallons)" at 1800 (the number of gallons of fuel to be carried in these tanks).

Repeat this procedure for the (2) Front Bomb Bay Tanks and for the 600 gallons of fuel in these tanks—also in Sector "2"; 120 gallons of oil—Sector "3"; 2-2000 pound Bombs—Sector "5"; and finally for the 400 pounds of cargo—Sector "6."

When this final operation has been made, read the Gross Weight on the Weight Scale as approximately 55,100 pounds.

(b) C.G. Determination

Using the opposite side of the Balodial from that used for the Gross Weight Determination:

First, set the index hair line on the "C.G.-Weight Grid" of the large dial at a point corresponding to the "Balodial Basic Weight" and C.G. of 33,600 lbs. and 3.98 feet aft of Datum. (This point can be closely approximated by interpolation between the 30,000 pound and 35,000 pound circular arcs and by interpolation between the 3.90 and 4.00 cross lines.)

Then move the rotating dial until the zero line (dotted radial line) of Sector "1" (Crew) coincides with the index hair line.

With the two dials fixed relative to each other, move the index until its hair line intersects the "Pilots" scale at "1" (the number of pilots).

With the index arm held stationary relative to the large dial, move the rotating dial until the zero line of Sector "1" again coincides with the index hair line.

With the two dials fixed relative to each other, move the index until its hair line intersects the scale marked "at Nose Compartment" at "1," thus adding in (1) Bomber.

In a similar manner, move the rotating dial until the zero line of Sector "1" again coincides with the index hair line and then move the index until its hair line intersects the "Top Gunner" scale at "1" (1—Top Gunner).

Next, move the rotating dial until the zero line of Sector "1" coincides with the index hair line, and then move the index until its hair line intersects the "Tail Gunner" scale at "1" (1—Tail Gunner).

Now, having added in all crew members to be carried in this particular loading, move the rotating dial until the zero line of Sector "2" (Fuel) coincides with the index hair line.

Then rotate the index arm until its hair line intersects the scale marked "Fuel—Main Wing Tanks (U. S. Gallons)" at "1800" (the number of gallons of fuel to be carried in these tanks).

Repeat the above procedure for the (2) Front Bomb Bay Tanks and for the 600 gallons of fuel in these tanks—also in Sector "2"; 120 gallons of oil—Sector "3"; 2-2000 pound bombs—Sector "5"; and finally for the 400 pounds of cargo, Station No. 7.2—Sector "6."

AFT BAY

When the final variable load item has been "added in," read the Center of Gravity on the "C.G.-Weight Grid" of the large dial at the intersection of the index hair line and the gross weight of 55,100 pounds determined in (a), above.

The C.G. will be found to be 4.89 feet aft of the Datum.

If it is desired to express the C.G. in % Mean Aerodynamic Chord, refer to the table in the Appendix, page 15, where it will be found by interpolation between the values listed that 4.89 feet aft of Datum is equivalent to 33.6% M.A.C.

2. C.G. Adjustment by Relocating Cargo

The above example gave a Gross Weight of 55,100 pounds at a C.G. of 4.89 feet aft of the Datum.

Suppose that it is desired to attain a C.G. of 4.60 feet aft of the Datum (30.8% M.A.C. from Appendix) by relocating the 400 pounds of cargo located in the vicinity of Station 7.2.

The location in the airplane to which the 400 pounds of cargo must be moved to give an airplane C.G. location equal to 4.60 feet aft of Datum is determined as follows:

With the index hair line in position on the "Center of Gravity-Weight Grid" values of 55,100 pounds and 4.89 feet aft of Datum, move the rotating dial until the 400 pound circular arc of the "Cargo Weight-Station Location Grid" in the "C.G. Adjustment Sector" (on the rotating dial) intersects the index hair line at the Station No. 7.2 cross line.

Then, with the two dials fixed relative to each other, move the index until its hair line intersects the 4.60 line of the "C.G.-Weight Grid" at the gross weight of 55,100 pounds.

It will be seen that the index hair line crosses the 400 pound arc of the "Cargo Weight-Station Location Grid" in the "C.G. Adjustment Sector" near the "Nose Compartment" line, thus indicating that the 400 pounds of cargo must be moved forward to the Nose Compartment to give a gross weight C.G. of 4.60 feet aft of the Datum.

3. Effect of Crew Movement on C.G.

As loaded in Example (2), the gross weight is 55,100 pounds at a C.G. of 4.60 feet aft of Datum.

Suppose, while in flight, it is desired to determine the effect on balance caused by moving the Tail Gunner forward to the Radio Operator's seat.

With the index hair line in position on the "C.G.-Weight Grid" at 55,100 pounds and 4.60 feet aft of Datum, move the rotating dial until the "Crew Location" scale in the "C.G. Adjustment Sector" of the rotating dial crosses the index hair line at the division marked "Tail Gunner."

Then, with the two dials fixed relative to each other, move the index until its hair line intersects the "Crew Location" scale at the division marked "Radio Operator."

Where the index hair line now crosses the 55,100 pound circular arc of the "C.G.-Weight Grid," read the C.G. of 4.42 feet aft of Datum (equivalent to 29.1% M.A.C.,—see Table in Appendix).

4. Gross Weight and C.G. Change for Partial Fuel Consumption.

Assume that the airplane when loaded with 1500 U. S. gallons of fuel in the Main Wing Tanks has a gross weight of 50,000 pounds at a C.G. of 4.80 feet aft of the Datum.

It is desired, in flight, to determine the gross weight and C.G. after the fuel has been reduced to 500 gallons.

(a) Gross Weight Determination

Set the index hair line on the weight scale at 50,000 pounds.

Move the rotating dial until the 1500 gallon division of the scale marked "Fuel—Main Wing Tanks (U. S. Gallons)" in Sector "2" lies on the index hair line.

Then, with the two dials fixed relative to each other, move the index until its hair line crosses the scale at 500 gallons.

On the weight scale, read the new gross weight of 44,000 pounds.

(b) C.G. Determination

Set the index hair line on the "C.G.-Weight Grid" at 50,000 pounds and 4.80 feet aft of the Datum.

Move the rotating dial until the 1500 gallon division of the scale marked "Fuel—Main Wing Tanks (U. S. Gallons)" in Sector "2" lies on the index hair line.

Then, with the two dials fixed relative to each other, move the index until its hair line crosses the scale at 500 gallons.

On the "C.G.-Weight Grid," at the intersection of the index hair line and the circular arc representing 44,000 pounds (the gross weight just obtained), read the C.G. of approximately 4.72 feet aft of Datum (equivalent to 32.0% M.A.C.,—see Table in Appendix).

BALODIAL BASIC WEIGHT AND C. G.

The term "Balodial Basic Weight" represents the gross weight of the airplane as flown less the variable load items.

In the case of the B-24D airplane, the variable load items consist of crew, fuel, oil, ammunition, bombs, cargo, auxiliary fuel tanks, and racks for the 4000 lb. external bomb installation on the wing.

The "Balodial Basic Weight" may also be defined as the actual weight empty of the airplane (according to AN weight statement) plus guns and plus equipment items usually carried in the airplane but not included in weight empty.

The B-24D airplanes on contracts 12464, 13281, 16005 and DA-4, can be divided into several groups which differ from one another principally because of differences in certain installations and equipment.

The "Balodial Basic Weight" for any of these groups of airplanes can be determined by adding to the weight empty obtained from an Actual Weight and Balance Report for a representative airplane, the weight of guns and equipment

usually carried in the airplane; or by weighing the airplane in a weight empty condition plus guns and equipment usually carried.

The "Balodial Basic Weight" for B-24D, Serial No. 41-11741 at time of delivery was approximately 33,600 lbs. at a C.G. of 3.98 feet aft of Datum Line of Page 16.

The derivation of these values is shown in Table I, below.

Table II comprises a list of weights, moment arms and moments of items normally included in "Balodial Basic Weight."

Table III comprises a list of weights, moment arms, and moments of items not normally included in the "Balodial Basic Weight."

Since items normally included in "Balodial Basic Weight" may not be carried at all times, since items not normally included in "Balodial Basic Weight" may sometimes be carried for a series of flights, and since installation and structural changes may be made from time to time, it is important that a "Balodial Basic Weight and Balance" Log be maintained so that a current "Balodial Basic Weight and Balance" will always be readily available.

TABLE I

Balodial Basic Weight for B-24D, Serial No. 41-11741

	Weight (Lbs.)	Arm (feet) Aft of Datum Line of Page 16	Moment (Ft.-Lbs.)
Weight Empty (from Actual Weight and Balance Report ZW-32-031, Page 10).....	32,574	3.57	116,221
Plus: Guns & Accessories (from Useful Load)			
At Top Turret (2- .50 Cal.)...	139	-2.0	-278
At Bottom Turret (2- .50 Cal.)	169	20.2	3414
At Tail Turret (2- .50 Cal.)...	176	44	7744
Equipment Items usually carried in Airplane but not included in Weight Empty of ZW-32-031			
Spare Tuning Units—Radio			
Forward (4)	78	-0.6	-47
Aft (2)	39	12.8	499
Navigating Equipment (In Part) "Standard Equipment"			
Drift Recorder	3	-16.3	-49
Astrograph and Ring	3	-13.9	-42
Astro-Compass	2	-14.5	-29
Drafting Machine	5	-12.6	-63
Drift Signals (12)	36	-2.5	-90
Flares, type 4.5 (12).....	99	20.5	2030
Tool Kits			
Engine (4)	28	22	616
Propeller (2)	25	19	475
Special (1)	28	20.4	571
Airplane Mooring Cases (4)			
Type D-1	44	19.6	862
Work Platform (1).....	25	24.3	608
Bomb Hoist and Supports (2)...	58	12.8	742
Bomb Slings (4), Handles (2), and Stowage	36	17.8	641
Thermos Jug	13	-0.6	-8
Blind Flying Curtains.....	4	-7.2	-29
Cushions			
Pilots' (2)	18	-8	-144
Radio Operator's (1)	9	-4.6	-41
At Station 7 (2).....	9	22	198
"Balodial Basic Weight".....	33,620	(3.98)	133,801

TABLE II

Items normally included in "Balodial Basic Weight"
of B-24D, Serial No. 41-11741

	Weight (Lbs.)	Arm (feet) Aft of Datum Line of Page 16	Moment (Ft.-Lbs.)
Armor			
Pilots'	230	-6.7	-1541
Aft of Bottom Turret.....	231	21.5	4967
Turrets			
Top (includes 82 lbs. Armor) ..	409	-2.0	-818
Bottom	387	20.2	7817
Tail (includes 156 lbs. Armor)	386	44.4	17138
Navigator's Dome	8	-15.6	-125
De-Icer Boots			
Wing	70	1.8	126
Tail	22	38	836
Anti-Icer Fluid (6 gallons).....	42	-2.0	-84
Heating and Ventilating System (Stewart-Warner)	102	-5.0	-510
Radio			
Command Set	98	8.7	853
Liaison Set	234	-4.5	-1053
Radio Compass	94	10.4	978
Interphone	52	0	0
Marker Beacon	4	7.3	29
Antenna Equipment	30	-2.4	-72
Provision for Radio	36	1.7	61
Spare Tuning Units			
Forward (4)	78	-0.6	-47
Aft (2)	39	12.8	499
	(665)	(1.88)	(1248)
Generators (4)	166	-0.5	-83
Batteries (3)			
Forward (1)	78	-5.8	-452
Intermediate (1)	78	-4.5	-351
Aft (1)	78	-2.7	-211
Oxygen Installation	183	4.0	732
Bomb Racks, Fuselage	250	7.2	1800
Automatic Pilot, Type A-3.....	84	-11.0	-924
Bomb Sight, Type O-2.....	100	-18.9	-1890
Navigating Equipment			
Computer	30	-12.9	-387

	Weight (Lbs.)	Arm (feet) Aft of Datum Line of Page 16	Moment (Ft.-Lbs.)
"Standard Equipment"			
Drift Recorder	3	-16.3	-49
Astrograph and Ring	3	-13.9	-42
Astro Compass	2	-14.5	-29
Drafting Machine	5	-12.6	-63
Drift Signals (12)	36	-2.5	-90
Flares, Type 4.5 (12)	99	20.5	2030
Tool Kits			
Engine (4)	28	22	616
Propeller (2)	25	19	475
Special (1)	28	20.4	571
Airplane Mooring Cases (4),			
Type D-1	44	19.6	862
Work Platform (1)	25	24.3	608
Fire Extinguishers			
Hand type			
Forward (1)	7	-10	-70
Aft (1)	7	17.3	121
Portable			
Forward (1)	11	-10	-110
Aft (1)	11	-5.5	-61
Entrance Ladder (1)	17	33	561
Bomb Hoists and Supports (2) ..	58	12.8	742
Bomb Slings (4), Handles (2), and Stowage	36	17.8	641
Thermos Jug	13	-0.6	-8
Blind Flying Curtains	4	-7.2	-29
Guns and Accessories			
At Top Turret (2- .50 Cal.)...	139	-2.0	-278
At Bottom Turret (2- .50 Cal.)	169	20.2	3414
At Tail Turret (2- .50 Cal.)...	176	44.0	7744
Cushions			
Pilots' (2)	18	-8	-144
Radio Operator's (1)	9	-4.6	-41
At Station 7 (2)	9	22.0	198

TABLE III

Items not normally included in "Balodial Basic Weight"

	Weight (Lbs.)	Arm (feet) Aft of Datum Line of Page 16	Moment (Ft.-Lbs.)
De-Icer Summer Fairing			
Wing	62	1.8	112
Tail	13	38	494
Hoisting Slings			
For Outer Panel (1)	7	26.5	186
For Airplane (1)	36	26.5	954
Life Rafts, Type A-2 (2)	112	4.3	482
Engine Covers (4)	69	26.5	1829

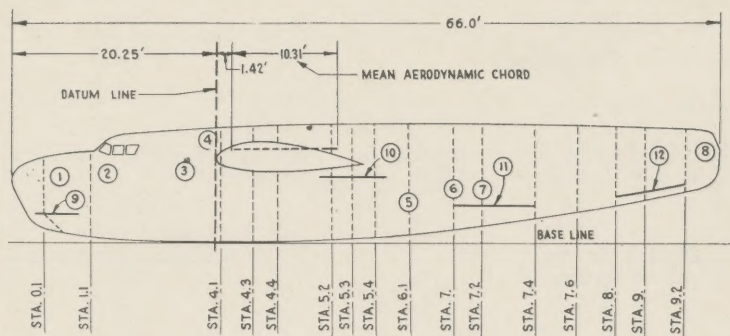
APPENDIX

Center of Gravity in Feet Aft of Datum Line vs. Center of Gravity in Per Cent Mean Aerodynamic Chord

The center of gravity as noted on the Balodial is given in feet aft of the Datum.

The location of the center of gravity is, however, often referred to in Per Cent of the Mean Aerodynamic Chord. The following table is therefore provided to show the relation between these two systems of notation.

Distance in feet Aft of Datum	% Mean Aerodynamic Chord
5.30	37.6
5.20	36.6
5.10	35.7
5.03 (Most Aft C.G. Limit)	35.0
5.00	34.7
4.90	33.7
4.80	32.8
4.70	31.8
4.60	30.8
4.50	29.9
4.40	28.9
4.30	27.9
4.20	26.9
4.10	26.0
4.00	25.0
3.90	24.1
3.80	23.1
3.79 (Most Forward C.G. Limit)	23.0
3.70	22.1
3.60	21.1
3.50	20.2



STATION LOCATION

STATION NO.	DISTANCE IN FEET FROM DATUM*
0.1	- 17.3
1.1	- 10.9
4.1	+ 0.1
4.3	+ 3.6
4.4	+ 5.5
5.2	+ 11.0
5.3	+ 12.8
5.4	+ 14.7
6.1	+ 18.2
7	+ 21.9
7.2	+ 25.6
7.4	+ 29.3
7.6	+ 33.0
8	+ 36.7
9	+ 39.3
9.2	+ 42.4

* DISTANCES AFT OF DATUM ARE POSITIVE (+)
DISTANCES FORWARD OF DATUM ARE NEGATIVE (-)

CREW LOCATION

ITEM NO.**	ITEM
1	AT NOSE COMPT.
2	PILOTS
3	RADIO OPERATOR
4	TOP GUNNER
5	BOTTOM GUNNER
6	AT STA. 7
7	SIDE GUNNER
8	TAIL GUNNER

CARGO LOCATION

ITEM NO.**	BAL-O-DIAL DESIGNATION
9	NOSE COMPT.
10	ABOVE REAR BOMB BAY (STA. 5.3)
11	STATION 7.2
12	STATION 9

** SEE CIRCLED NUMBERS ON ABOVE DIAGRAM

NOTES:

1. DO NOT SCALE
2. ALL STATION NOS LISTED HERE ARE STENCILED IN AIRPLANE.

STATION DIAGRAM MODEL B-24D AIRPLANE CONSOLIDATED AIRCRAFT CORPORATION

